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13. ABSTRACT (Maximum 200 words) A novel scheme for ultrafast all-optical switching in a semiconductor NLDC has been investigated numerically. The operating characteristics of a model switch have been demonstrated: Switching speed 2 Tbit/s, zero device recovery time, switching contrast ratio 10/1, low cross-over pulse energy for switching (below 30 pJ). The latency time per switch has been estimated to be 40 ps for the NLDC coupling length 1 mm. The stability analysis has shown that the novel scheme is robust to most common physical perturbations.					
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Submitted to: Dr. Arje Nachman, AFOSR/NM

From: Dr. I. Talanina, Optical Sciences Center, University of Arizona, Tucson AZ 85721

Date: 8 September, 1997

Re: Grant F4962097-10180: Summary of the results obtained since 13 June, 1997

- As a part of the device optimization task, the search for a semiconductor material which would allow tunable operation in the spectral region close to  $1.5 \mu m$  (the optical communications wavelength) has been performed. The suitable material has been found: PbS quantum dots (QDs). The recent experimental results on absorption saturation in strongly confined PbS QDs (an average dot radius of  $4 nm$ ) at room temperature have shown a large nonlinear optical response obtained with modest energy and a fast response time [1]. PbS doped glass has a broad excitonic absorption band (about  $63 meV$  FWHM) spectrally centered at  $\lambda = 1.38 \mu m$  and a large exciton binding energy ( $\hbar\omega_b \sim 200 meV$ ). This material would be a prime candidate for the resonant optical switching applications in  $1.3$ - $1.5 \mu m$  spectral range. Modeling of the resonant NLDC operation with PbS doped glass as a material for the constituent waveguides is a future theoretical task.
- In our June/97 report, the operating characteristics of a model resonant soliton switch were demonstrated in numerical simulations with  $100 fs$  input pulses using II-VI MQWs material parameters: Switching speed  $2 Tb/s$ , zero device recovery time, high switching contrast ratio ( $10/1$ ), low cross-over pulse energy for switching (below  $30 pJ$ ). The device latency time was not discussed. The latency constraint is not equivalent to switching speed. For example, one could implement an all-optical switch using the ultrafast index nonlinearities of fiber optics in a nonlinear optical loop mirror (NOLM) configuration. The fiber NOLMs rely on a nonlinear phase shift to induce the switching, and with the extremely weak  $\chi^{(3)}$  nonlinearity of fibers, long interaction lengths are required. It inevitably leads to severe latency. That is, although the switching action may be ultrafast, the time between the point at which the signal enters the switch

and the point at which it exits can be as long as several hundred nanoseconds. Such long latencies per switch are completely unacceptable for implementing a computing network.

The resonant NLDC features minimal latency time. Simple estimation shows that, for a device coupling length of about 1 mm and an average pulse propagation velocity of  $2.5 \times 10^7$  m/s (the data are taken from our numerical simulations), the latency time per switch is as short as 40 ps. Note that this is about an order of magnitude better than the typical latencies of electronic switches [2].

- We have performed numerical simulations with III-V GaAs/AlGaAs MQW material parameters (in addition to our previous results obtained with II-VI semiconductors). The major operating characteristics of the resonant NLDC (switching speed, device recovery time, switching contrast ratio) are not sensitive to the choice of the semiconductor material parameters, but the cross-over pulse energy for switching is. The latter one is inversely proportional to the squared dipole moment of the excitonic transition and the excitonic binding energy (through the  $\beta_1$  nonlinear parameter). It's highly desirable to use the materials with strong transition dipole moment and large exciton binding energy to minimize the input energy requirements.
- At the present stage, the major theoretical challenge is to prove that the resonant optical switches would permit various logic gate functions in the same way how the electronic switches do [2]. While this task is very time consuming and beyond the scope of the initial proposal, it is crucial for future applications, therefore, a background theoretical research on the topic has been already started.

[1] J. Butty, G.E. Jabbour, H. Tajalli, N. Peyghambarian, and N.F. Borrelli, Internal progress report, Optical Sciences Center, University of Arizona, to be published.

[2] "Principles of CMOS VLSI Design. A Systems Perspective" N.H.E. Weste and K. Eshraghian (Second ed.), Addison-Wesley Publ. Company, 1995.